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WEO 2009 Flowcharts

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Flowchart Representations of the 2009 World Energy Outlook

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Abstract

Flow charts depicting global energy use have been generated to represent the data in the International Energy Agency's 2009 World Energy Outlook. These charts describe actual global energy use in 2007 as well as projected energy use in 2030 under a "reference" scenario and a scenario in which carbon emissions are limited (by allowing a carbon market to develop) such that the long-term atmospheric concentration of CO_2 does not exceed 450 ppm.

Introduction

Lawrence Livermore National Lab (LLNL) has published flow charts (also referred to as "Sankey Diagrams") of important national commodities since the early 1970s. The most widely recognized of these charts is the U.S. energy flow chart (Livermore, 2009) , however, Livermore has also published charts depicting carbon (or carbon dioxide potential) flow and water flow at the national level as well as energy, carbon and water flows at the international, state, municipal and organizational (eg. Air Force) level. Flow charts are valuable as single-page references that contain quantitative data about resource, commodity and byproduct flows in a graphical form that also conveys structural information about the system that manages those flows.

At the request of the Chevron Corporation, LLNL has analyzed the scenarios in the International Energy Agency's World Energy Outlook (International Energy Agency, 2009), and transformed the tabular data into flow charts.

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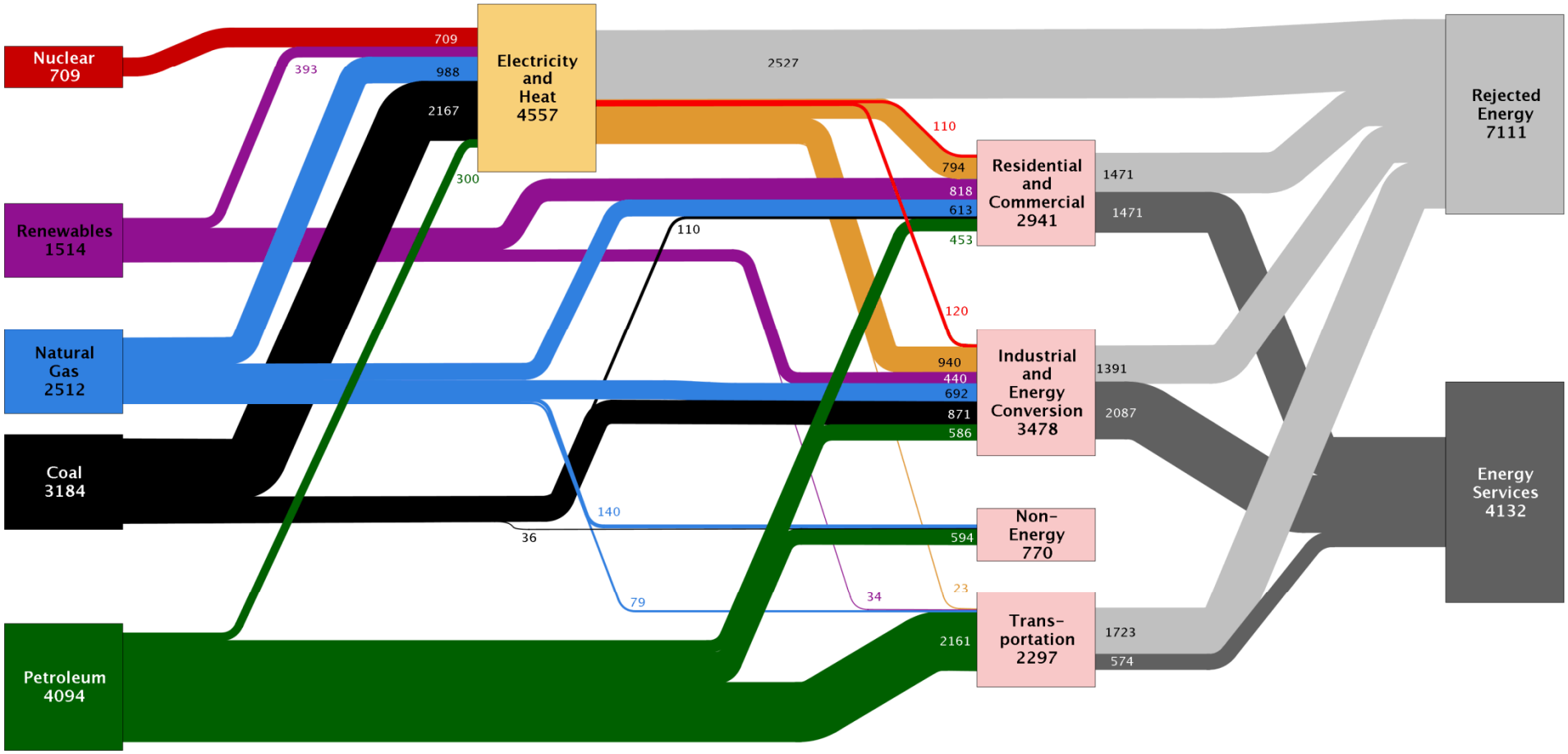
World Energy Flow in 2007: 12,013 Mtoe
WEO 2009



Source: LLNL 2010. Data is based on OECD/IEA's World Energy Outlook 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Renewable energy includes Solar PV, Solar Thermal, Biomass, Geothermal, Hydroelectricity and Wind. Industrial and Energy Conversion includes industrial energy use as well as energy used to drive resource extraction, petroleum refining and gas- and coal-to-liquids conversions. End use efficiencies are assumed to be 50% (Residential/Commercial), 60% (Industrial/Conversion) and 25% (Transportation). Totals may not equal sum of components due to independent rounding. LLNL-TR-xxxxxx.

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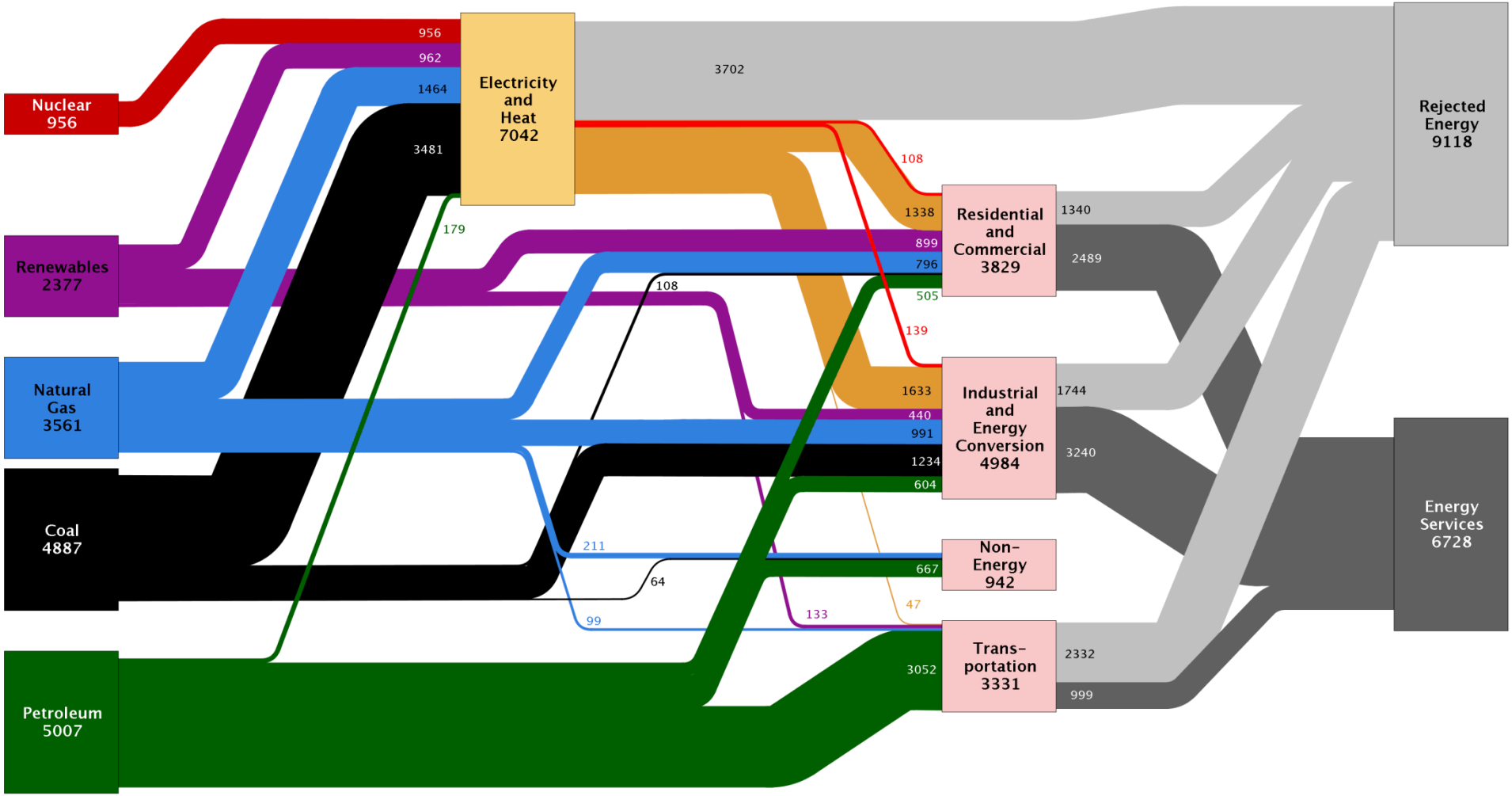
Projected World Energy Flow in 2030: 16790 Mtoe
WEO 2009 Reference Scenario



Source: LLNL 2010. Data is based on OECD/IEA's World Energy Outlook 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Renewable energy includes Solar PV, Solar Thermal, Biomass, Geothermal, Hydroelectricity and Wind. Industrial and Energy Conversion includes industrial energy use as well as energy used to drive resource extraction, petroleum refining and gas- and coal-to-liquids conversions. End use efficiencies are assumed to be 65% (Residential/Commercial), 65% (Industrial/Conversion) and 30% (Transportation). Totals may not equal sum of components due to independent rounding. LLNL-TR-xxxxxx.

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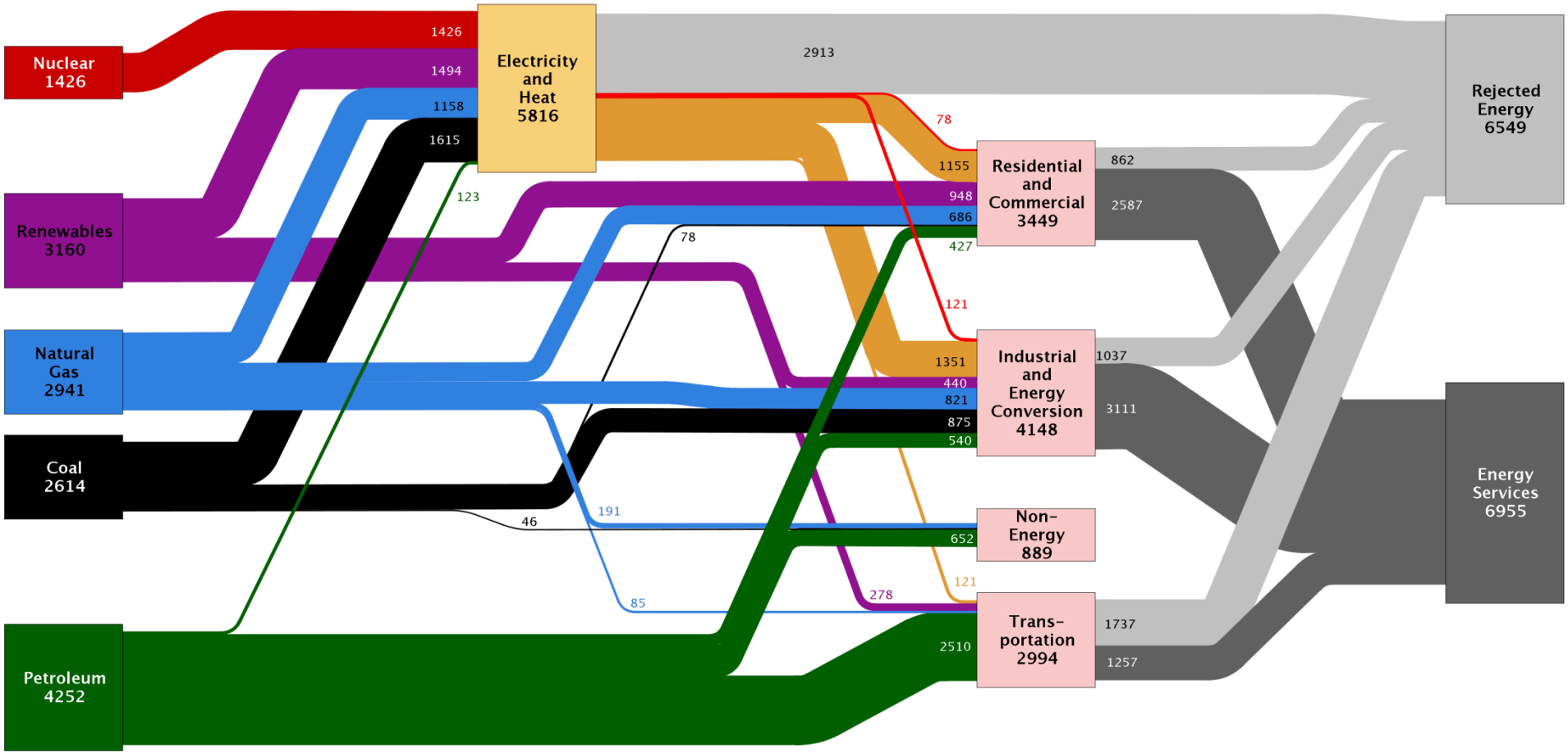
Projected World Energy Flow in 2030: 14,389 Mtoe
WEO 2009 450ppm Scenario



Source: LLNL 2010. Data is based on OECD/IEA's World Energy Outlook 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Renewable energy includes Solar PV, Solar Thermal, Biomass, Geothermal, Hydroelectricity and Wind. Industrial and Energy Conversion includes industrial energy use as well as energy used to drive resource extraction, petroleum refining and gas- and coal-to-liquids conversions. End use efficiencies are assumed to be 75% (Residential/Commercial), 75% (Industrial/Conversion) and 42% (Transportation). Totals may not equal sum of components due to independent rounding. LLNL-TR-xxxxxx.

Analysis

This analysis traces the flow of energy from resources that exist in the environment through end-use and disposition. The World Energy Outlook (WEO) provides quantitative information regarding the use of Nuclear, Natural Gas, Coal and Petroleum resources. It also provides quantitative estimates of the aggregate use of renewable (Solar, Wind, Geothermal, Hydroelectric and Biomass) energy. However, the report is incomplete in its quantitative analysis of each component of renewable energy. In the absence of further analysis and comparison to other International Energy Agency (IEA) publications, this report was not prepared to chart those quantities.

The statistical arm of the IEA tracks energy from natural resources through a matrix of energy transformations (including resource extraction, petroleum refining, gas-to-liquids processes, electricity generation, etc.) to a small set of end use sectors. WEO reports gross consumption related to the transformation sector, and includes a detailed breakdown of energy used in the production of electricity. Given that electricity is treated with "special" status, and that the balance of energy used in the transformation sector is not reported in detail, the following analysis makes the assumption that non-electricity based energy transformations (such as petroleum refining) are part of the "industrial" sector.

Flows of energy on the flow chart were calculated as follows:

The following flows of energy are taken directly from WEO Table 2.9:

Inputs to Electricity and Heat:
Nuclear → Electricity = Total Primary Energy Demand: Nuclear
Gas → Electricity = Power Generation: of which gas
Coal → Electricity = Power Generation: of which coal
Inputs to Residential and Commercial:
It is assumed that "Other Sectors" are equivalent to Residential and Commercial
Renewables → Res/Comm
Gas → Res/Comm
Coal → Res/Comm
Oil → Res/Comm
Electricity → Res/Comm
Heat → Res/Comm
Inputs to Industry and Other Energy:
Heat → Industry
Inputs to Transportation:
Renewables → Transportation = Transport: Biofuels
Petroleum → Transportation = Transport: Oil

The rest of the flows are computed in the following order:

1) **Oil → Electricity** is computed from the quantity of electricity (TWh) generated from oil, converted to a heat rate using an assumed efficiency of 32% and the conversion from TWh to Mtoe in the "General Conversion Factors for Energy" in the appendix.

2) **Renewables → Electricity** is computed by subtracting the sum of the contributions from [Nuclear, Gas, Coal and Oil] to the total of Power Generation.

3) **Electricity → Transportation** is computed by subtracting the sum of electricity used by industry and by the residential/commercial sectors from the total final consumption of electricity.

4) **Natural Gas → Electricity** is computed by subtracting transportations consumption of the sum of [Renewables, Oil and Electricity] from the total energy consumed by the transportation sector.

5) **Coal → Non Energy** is computed by subtracting the sum of coal consumption by [Industry and Residential/Commercial] from the Total Final Consumption of Coal.

6) **Natural Gas → Non Energy** is computed by subtracting the sum of gas consumption by [Industry, Residential/Commercial and Transport] from the Total Final Consumption of Natural Gas.

7) **Oil → Non Energy** is computed by subtracting the non-energy use of gas and coal from the total of non-energy consumption.

8) **Coal → Industry/Other** is computed by adding the industrial consumption of coal to the total primary consumption of coal and then subtracting the total final consumption of coal and electricity's consumption of coal.

9) **Oil → Industry/Other** is computed by adding the industrial consumption of oil to the total primary consumption of oil and then subtracting the total final consumption of oil and electricity's consumption of oil.

10) **Natural Gas → Industry/Other** is computed by adding the industrial consumption of gas to the total primary consumption of gas and then subtracting the total final consumption of gas and electricity's consumption of gas.

11**) Renewables → Industry/Other** is computed by adding the industrial consumption of renewables to the total primary consumption of renewables and then subtracting the total final consumption of renewables and electricity's consumption of renewables.

12) **Electricity → Industry/Other** is computed by subtracting Industry/Other's consumption of [Coal, Oil, Natural Gas and Renewables] from the sum of the total energy consumption by the Industry and Other Energy sectors.

The following End Use Efficiencies are assumed (based on qualitative statements in WEO 2009 about assumed efficiency improvements):

	Scenario		
Sector:	**2007**	**2030 Reference**	**2030 450ppm**
Residential/Commercial	50%	65%	75%
Industrial/Other Energy	60%	65%	75%
Transportation	25%	30%	42%

Conclusion

The flow chart described in this report is a compact depiction of the national water use data contained in the USGS report on water use in the United States in 2005. This diagram is available at:

http://flowcharts.llnl.gov

References

Lawrence Livermore National Lab, 2009, Energy Flow Chart. Available at : http://flowcharts.llnl.gov (Livermore, 2009)

International Energy Agency, 2009, World Energy Outlook. IEA Publications, Paris. ISBN-13: 978 92 64 06130-9